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The relationship of land use practices to surface water quality in the Upper Oconee Watershed of Georgia

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Abstract

On a watershed scale, geospatial information can be used to identify water resources that are least buffered from contamination. Implementing conservation practices at these locations may accelerate the process of increasing a watershed's ability to support its designated uses. The Upper Oconee Watershed of Georgia contains land areas devoted to poultry, dairy, and beef production. Within these historically agricultural lands, urbanization is proceeding rapidly around existing cities. Agricultural production practices are concentrated in the watershed with poultry in the headwaters area and dairy near a major lake (Lake Oconee). The objective of this research was to relate data sets representing surface water quality at selected sites throughout the watershed to the predominant land use in that portion of the watershed. The location of 550 poultry operations in the headwaters of the Upper Oconee Watershed, away from the city of Athens GA, has minimized conflicts between agricultural and urban interests. Phosphorus, nitrogen, and fecal coliform bacteria were high near the poultry production area, but were reduced within the watershed prior to reaching the intake for the municipal water supply. Athens had a large impact on surface water quality and approximately doubled the amount of phosphorus and nitrogen in the Oconee River. The Oconee River contributed approximately 70% of the water flowing to Lake Oconee. The residents of Lake Oconee have noted the 30 dairies located west of the lake impacting two relatively minor creeks flowing to the lake. These two creeks make up approximately 2.5% of the flow to the lake, but the proximity of the dairies to the lake makes losses of phosphorus, nitrogen, and fecal bacteria apparent in water samples. Fecal coliform numbers were elevated in some creeks with little agricultural or urban development. To test alternative microbial assays, surface water from a grazed watershed was compared to water from a wooded watershed. Assays for enterococci and *E. coli* may provide a better test for fecal contamination and allow differentiation between natural areas and areas impacted by grazing animals. Analysis of the Upper Oconee Watershed identified agricultural impacts and areas that should be priorities for natural resource management to reduce agricultural non-point source pollution. Focusing conservation efforts at these locations may prevent agricultural–urban conflict. However, the data also indicate that municipal sources of nutrients and fecal bacteria must be reduced to make significant progress in the watershed.

Keywords: Grazing lands; Dairy; Poultry; Urban; Manure; Coliform bacteria

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1. Introduction

Conservation practices have often been located by visual inspection of the landscape and funded by government organizations, based upon the willingness of producer cooperators to implement a practice. On both a farm and watershed basis, geospatial data can be used in the decision making process to maximize the returns in resource conservation.

The Southern Piedmont of the Eastern USA covers 16.5 million hectares, from Alabama to Virginia along the east face of the Appalachian Mountains. The Piedmont is characterized by rolling topography with abundant precipitation and surface water resources. In the Southern Piedmont, many watersheds contain mixtures of confined animal production and extensive pasture-based beef production and forestry. Urban development has been rapid and has impacted water resources through both an increased demand and an increased load of nutrients and microbes from municipal wastewater. In order to avoid agricultural–urban conflict, sources of agricultural pollution must be identified and conservation practices implemented proactively. On a watershed basis, analysis of geospatial information can identify agricultural production practices that pose the greatest threat to water resources. Implementing conservation practices, and focusing dollars set aside for conservation practices on these locations could accelerate efforts to increase the ability of the watershed to support all of its designated uses.

Confined animal production and dairy production are often concentrated in the watershed. The location of these concentrations within the watershed relative to municipal water supplies and recreational areas can be a source of conflict. In contrast, beef production is often widely distributed throughout the watershed. Beef production includes calf production, and this practice presents some unique challenges. In some beef production systems, planned animal movements can prevent concentrating animals in a limited area for extended periods to minimize the concentration of nutrients and feces. However, cow–calf pairs are difficult to move in the first few weeks after calving. Producers also concentrate animals just prior to calving to simplify observation. Land application of waste from confined animal operations is also often associated with areas for beef production , but most of the waste is distributed on pastures near (<10 km) the confined animal operation. These practices may pose environmental hazards by concentrating nutrients, exposing soil to erosion, and creating a potential for runoff of fecal bacterial. Problems are exacerbated in those portions of a watershed where large quantities of feed are imported for confined animal production with limited area available for manure distribution. The clustering of various agricultural production practices within a watershed, coupled with growing urban areas, makes water quality issues, and potential urban–agricultural conflicts, geospatial in nature.

2. Description of the Upper Oconee Watershed

The Upper Oconee Watershed (HUC 03070101) is located within the Southern Piedmont, and covers approximately 7580 km^2 (Fig. 1). The watershed includes over 4000 km of continuously flowing streams (EPA, 1997a). The human population of the watershed was estimated to be 269,000 in 1990, and has continued to grow over the past decade. Total withdrawals of water were 4973 million liters/day in 1990 and, of that total, 98% of the withdrawals was surface water (EPA, 1997a). Agriculture accounts for <1% of the water withdrawn from the watershed, but the potential for agricultural impact on surface water quality is large, with many confined animal production systems (primarily poultry) and extensive grazing lands. The current rapid urbanization makes this an important time to find effective means of reducing negative agricultural impacts on water quality. The headwaters of the North Oconee, Middle Oconee, and Mulberry rivers are in the northern portion of the watershed. The North Oconee flows through the middle Piedmont to the major regional city of Athens. The Mulberry River flows into the Middle Oconee River to the west of Athens. South of Athens, the North Oconee and Middle Oconee rivers merge and flow through predominantly agricultural lands to Lake Oconee and Lake Sinclair. Lake Oconee is a Georgia Power reservoir and provides hydroelectric power, real estate development, and recreational areas. As evidenced by an active Adopt-a-Stream program, people from all sectors of the economy are concerned about water-quality issues as related to recreation, tourism, human health, fishing, real estate values, and wildlife habitat.

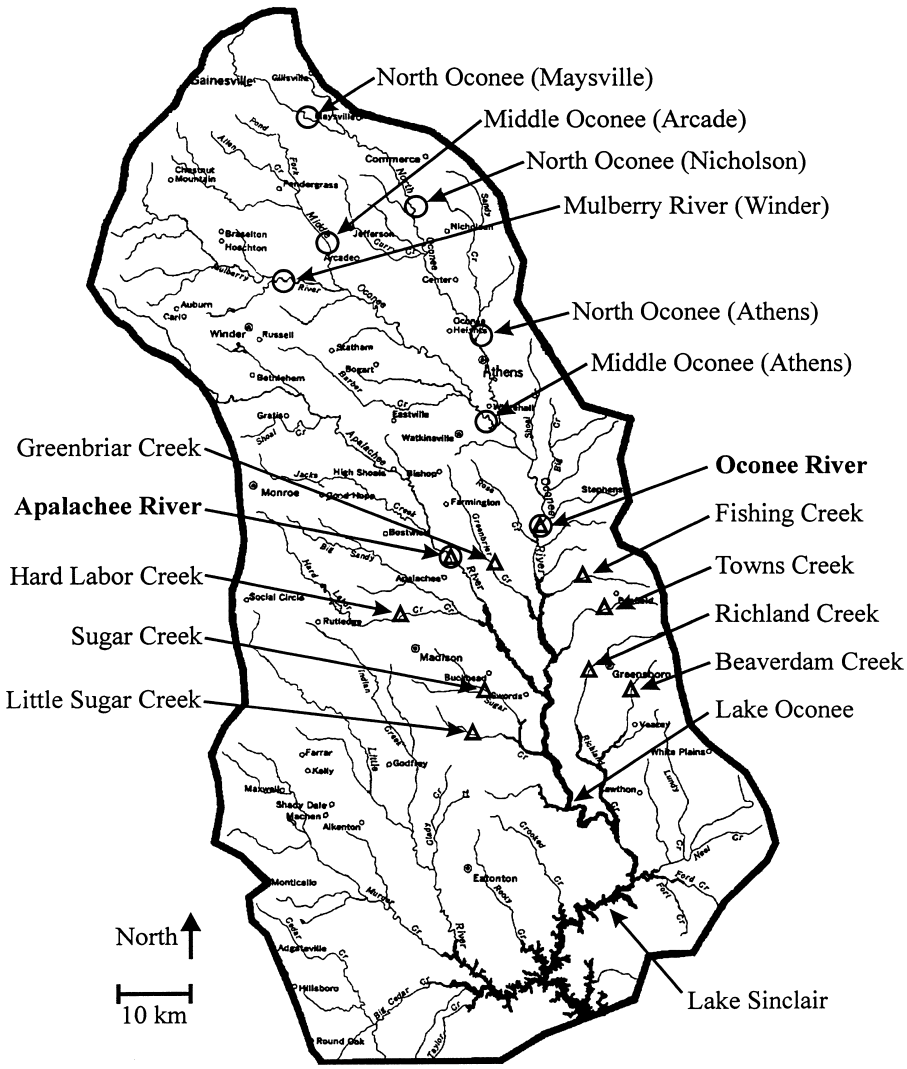

Fig. 1. The Upper Oconee Watershed of Georgia, USA, with selected sampling sites from Georgia Environmental Protection Division (circles) and Georgia Power (triangles) databases.

Animal production provides the largest agricultural income as well as employment to many residents of the Upper Oconee Watershed. Animal production systems for poultry and dairy use large quantities of feeds that are imported into the watershed and use manure disposal strategies that may lead to nutrient enrichment and degradation of watersheds. The manure produced by poultry operations is often land applied as a source of fertilizer for pastures grazed by beef cattle. Liquids from lagoons associated with dairy production are often sprayed through irrigation systems onto nearby fields for fertilization.

3. Description of water quality data

In order to test for practices impacting water quality within the Upper Oconee watershed, data collected by the Georgia Environmental Protection Division (GA EPD) (EPA, 1997b) in 1996 and data collected by

Georgia Power Company (Georgia Power, personal communication) in 1995 and 1996 were acquired. The variables reported are turbidity (Hach units), concentrations of phosphorus (mg/l), nitrogen (mg/l), and fecal coliform bacteria. The coliform bacteria are enumerated by presence and absence in serial dilutions and reported as most probable number (MPN) per 100 ml. The GA EPD data set contains one observation per month for a year at each location ($n = 12$). The Georgia Power locations were sampled approximately every two weeks from February 1995 through April 1996 ($n = 18$–20). Preliminary data analysis indicated that a log transform was required to normalize the estimates of turbidity, phosphorus, and fecal coliform numbers in both data sets. The transform was not needed for the nitrogen data from either source. The two data sets were tested by analysis of variance of the transformed data with a model that included collection date and site (SAS, 1994). Means were separated with a Waller–Duncan *k*-ratio *t*-test, with a *k*-ratio of 100. Letters were assigned to indicate significant differences and then the means were converted back to the original units for presentation.

Flow data was available for the Georgia Power sample sites and preliminary analysis indicated that a log transformation was also required to normalize this variable. The flow data was unbalanced across sites (*n* ranged from 21 to 33), so least squares means are reported. As with the other variables, tests were performed on the transformed variables and then the data were converted to the original units for presentation in tables.

The objective of this research was to test for impact of agricultural practices on surface water quality. The focus was on two portions of the Upper Oconee Watershed, as compared with other portions of the watershed. The first area was in the headwaters of the North Oconee, Middle Oconee, and Mulberry rivers, in which a high concentration of poultry production is located, and, secondly, west of Lake Oconee where dairy production is concentrated. In addition, a simultaneous comparison of estimates of total coliforms, *E. coli*, and enterococci in grazed and forested miniature watersheds was included to test two alternative microbial indicators that may be more representative of domestic animal impact than traditional coliform analysis.

4. Headwaters area of the North Oconee, Middle Oconee, and Mulberry rivers

This area is comprised of approximately 100 000 ha in the northern portions of the Upper Oconee Watershed (NRCS, personal communication). The area cleared for agriculture is estimated to be 20 000 ha. The principal agricultural enterprises include beef, poultry, and timber production. In this area, there are approximately 550 poultry operations that produce 64 million broilers per year and manage 2 million layers. In addition, more than 33,000 beef cattle graze in this part of the watershed. These poultry and beef operations produce enough N in manure each year to apply 457 kg N agricultural hectares/year. The data collected by GA EPD (EPA, 1997b) were used to study surface waters likely to be impacted by agricultural production in this portion of the watershed. From the available data, 8 sites were selected. Three sites are located downstream from the impacted area (Fig. 1, indicated by circles). They are the North Oconee (Maysville), Middle Oconee (Arcade), and the Mulberry River (Winder) sites. Impact further downstream in the watershed was assessed with the following four sample sites: North Oconee (Nicholson), North Oconee (Athens), Middle Oconee (Athens), and the Oconee River just above Lake Oconee. For comparison, samples from the Apalachee River were included to represent a portion of the watershed with less impact from agriculture and urban development.

5. West of Lake Oconee

This central portion of the Upper Oconee Watershed is west of Lake Oconee and is comprised of approximately 83 000 ha that is drained by Hard Labor, Sugar, and Little Sugar creeks (Fig. 1). The total area cleared for agriculture is estimated to be 26 000 ha. The principal agricultural enterprises include dairy, beef, poultry, and timber production. There are approximately 30 dairies and 30 poultry operations in the area. More than 21,000 beef cattle graze in this portion of the watershed. These operations produce enough N in waste each year to apply approximately 200 kg/agricultural ha/year (NRCS, personal communication). Water quality data made available by Georgia Power Company were used to study surface waters likely to be impacted by agricultural production in this portion of the watershed. A total of 10 sites (indicated by triangles in Fig. 1) were summarized. The Hard Labor, Sugar, and Little Sugar sampling sites represent the area previously described. The Apalachee River, again, represents a site with lower agricultural and urban impact. For comparison, the following sites located around Lake Oconee were included; Greenbrier Creek, the Oconee River, Fishing Creek, Towns Creek, Richland Creek, and Beaverdam Creek.

6. Results

6.1. Headwaters area of the North Oconee, Middle Oconee, and Mulberry rivers

Turbidity was lower at the Apalachee River site than the other sites used to examine this portion of the watershed and no other sites had lower P, N, or fecal coliform concentrations than the Apalachee River site (Table 1). The Maysville site on the North Oconee, the Arcade site on the Middle Oconee, and the Mulberry River site had levels of N that were higher than samples collected at the North Oconee (Athens) site. The Maysville site showed the greatest impact in P, N, and fecal coliforms and it was higher than the North Oconee (Nicholson) site located about 20 km downstream. Although coliform numbers at the Maysville site were higher than at the downstream Nicholson site, there was no significant difference in coliform numbers between Maysville and the North Oconee (Athens) site further downstream. Urban runoff may increase fecal coliforms and the land use practices between Nicholson and Athens deserve further study because the North Oconee River is the source of the Athens drinking water supply. Reduced application of poultry litter away from the headwaters area resulted in the portions of the watershed between Athens and the poultry production area improving water quality by reducing P, N, and fecal coliform bacteria.

No significant effect was seen between the sites on the Middle Oconee (Arcade and Athens) and the Mulberry River (Winder). This may have been because the northern sites on the Mulberry River and on the Middle Oconee at Arcade were not as close to the poultry production area as the Arcade site on the North Oconee.

A pronounced difference in the P and N concentration occurred between the sample sites just above Athens and the site located on the Oconee River south of Athens. Mean P doubled from 0.048 mg/l in the North Oconee near Athens and 0.041 mg/l in the Middle Oconee near Athens to 0.092 mg/l in the Oconee River just above Lake Oconee. Nitrogen increased from 0.53 and 0.78 mg/l north of Athens to 0.96 mg/l near Lake Oconee. Both of the Athens sample sites were upstream from the wastewater treatment plant and this effect is attributable to urban impact via municipal discharge. Athens withdraws water at the reported test site on the North Oconee River and discharges waste into the Middle Oconee River near the confluence of the two rivers.

6.2. West of Lake Oconee

Sample sites were obtained that represent the major rivers and creeks that drain into Lake Oconee (Table

Table 1
Annual means of monthly water quality samples from 8 sites in the Upper Oconee Watershed, Georgia, sampled once a month in 1996 ($n = 12$) (Data from EPA STORET)

Sampling site	Turbidity (Hach)	P (mg/l)	N (mg/l)	Fecal coliforms (MPN/100 ml)[a]
North Oconee (Maysville)	27 a	0.080 ab	0.86 ab	1270 a
North Oconee (Nicholson)	22 a	0.050 c	0.58 d	439 bc
North Oconee (Athens)	23 a	0.048 cd	0.53 d	613 abc
Middle Oconee (Arcade)	27 a	0.048 cd	0.85 ab	916 ab
Middle Oconee (Athens)	25 a	0.041 cd	0.78 bc	427 bc
Mulberry River (Winder)	28 a	0.060 bc	0.79 abc	791 abc
Oconee River	24 a	0.092 a	0.96 a	639 abc
Apalachee River	14 b	0.030 d	0.67 cd	364 c

[a] MPN, most probable number by presence and absence in serial dilutions.

Table 2
Annual mean estimates of biweekly water quality samples from 10 rivers and creeks, 1995 ($n = 20$–29), near Lake Oconee, Georgia (Data from Georgia Power)

Sampling site	Flow (l/s)	Turbidity (Hach)	P (mg/l)	N (mg/l)	Fecal coliforms (MPN/100 ml)[a]
Oconee River	42882 a	24 a	0.082 a	0.85 a	518 abcd
Apalachee River	10904 b	19 bc	0.032 cd	0.49 cd	163 e
Hard Labor Creek	4595 c	20 ab	0.036 cd	0.39 e	281 de
Fishing Creek	812 d	12 de	0.034 cd	0.10 g	354 cd
Sugar Creek	799 d	17 bc	0.104 a	0.56 c	1.041 a
Greenbrier Creek	706 d	20 ab	0.038 c	0.53 cd	385 cd
Little Sugar Creek	546 e	18 bc	0.089 a	0.66 b	915 ab
Beaver Dam	341 f	10 e	0.036 cd	0.21 f	325 de
Richland Creek	262 f	12 de	0.053 b	0.48 d	690 abc
Towns Creek	154 g	15 cd	0.029 d	0.12 g	485 bcd

[a] MPN, most probable number by presence and absence in serial dilutions.

2). Even though the time interval and dates differed for estimates of turbidity, P, and N, the Oconee and Apalachee Rivers are similar to those estimated by the Georgia EPD.

The volume of water from the Oconee River flowing into Lake Oconee relative to other sources is so large that it makes a natural focus for conservation practices (Table 2). Reducing the influx of P and N from the city of Athens is a priority. From the confluence of the North and Middle Oconee Rivers just south of Athens, the river flows through forested and agricultural land to the lake. Agricultural impacts are likely to be similar to those noted for Greenbrier Creek with the elevated P and N attributable to the city of Athens. Agricultural impact from the concentration of dairy production was evident on Sugar and Little Sugar Creek, with P and fecal coliform levels elevated to concentrations similar to those in the Oconee River flowing from Athens. In Little Sugar Creek, the concentrations of N were lower than in the Oconee, but higher than Greenbrier Creek. In Sugar Creek, concentrations of N were similar to Greenbrier Creek. The portions of the watershed drained by Sugar and Little Sugar Creek merit a focused effort to reduce nutrient loading to prevent localized problems in Lake Oconee, but the sum of their flows is less than 2.5% of the Oconee River flow. Sugar and Little Sugar Creeks have already attracted the attention of residents of the lake (Oconee Lake Watch, personal communication). Fishing and Towns Creeks are low in P and N and flow primarily from National Forest. Richland Creek is impacted by wastewater from the municipality of Greensboro and had elevated P and coliforms. Hard Labor and Beaverdam Creeks have mixtures of activities affecting the water quality, but are low in P and only Fishing Creek and Towns Creek have lower N.

Fecal coliform concentrations from relatively minor sources of water can be a problem in the lake. Fecal microbe concentrations span orders of magnitude and, therefore, relatively small creeks can have a disproportionate impact on the ability of the lake to support its designated uses. Sugar Creek drains a relatively small watershed near the lake while the Oconee River contains runoff from most of the northern half of the watershed. The flow of Sugar Creek to Lake Oconee was approximately 1% of the flow of the Oconee River. However, because of the proximity of the watershed drained by Sugar Creek to Lake Oconee it was especially prone to deliver large numbers of fecal coliform bacteria (Fig. 2).

Two notable spikes in numbers of fecal coliform bacteria occurred in the available data. The first case, both the Oconee River and Sugar Creek contained more than 600 000 MPN/100 ml. Water near the northern portion of the lake would have exceeded the recommended recreational limits of 200 MPN/100 ml. The Apalachee contained approximately 1000 MPN/100 ml at that time, but soon returned to approximately 100 MPN/100 ml. During the second spike, the Oconee River counts did not exceed 600–700 MPN/100 ml, but Sugar Creek, again, was found to be in excess of 600 000 MPN/100 ml. Sugar Creek contained fecal coliform numbers that were three orders of magnitude greater than the Oconee River

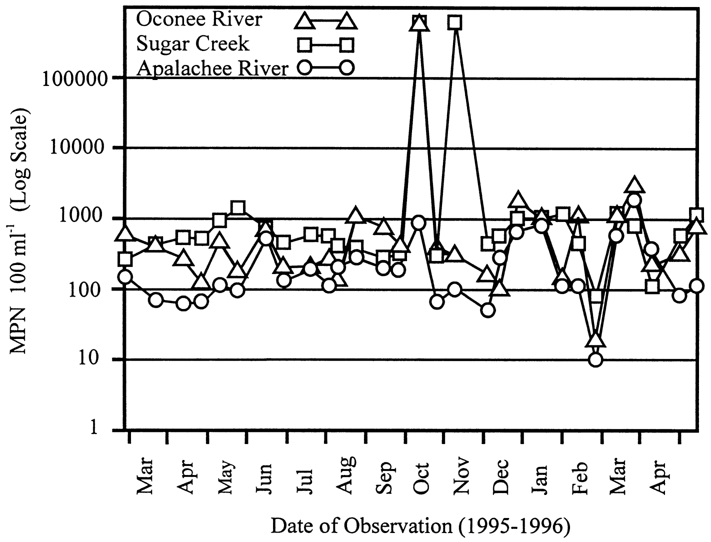

Fig. 2. Most probable number (MPN) of fecal coliform bacteria per 100 ml in the Oconee River (triangles), Sugar Creek (squares), and the Apalachee River (circles) near Lake Oconee from a database provided by Georgia Power Company.

and could have presented a hazard to recreation in the lake. These effects may be important even if they are localized to a particular portion of the lake and justify an increased focus on a smaller source of water representing only a limited portion of the watershed. However, fecal coliforms may not be the best indicator of fecal contamination. Towns Creek and Fishing Creek, which flow primarily through national forest, had fecal coliform levels that were not significantly different from Little Sugar Creek (Table 2).

6.3. Cattle impacts on fecal bacteria in surface water

The presence of relatively high numbers of coliform bacteria in areas with few domestic animals and otherwise high water quality (low P and N) such as Towns Creek and Fishing Creek indicate that an alternative microbial method is needed when testing for fecal contamination of water.

Two small watersheds located on the USDA-ARS J. Phil Campbell, Sr., Natural Resource Conservation Center were used to compare numbers of total coliform, enterococci, and *E. coli* bacteria in surface water of a small wooded watershed to a small grazed watershed. Animals in the grazed watershed had access to the creek and the creek flowed into a pond. Both watersheds had springs. The grazed watershed presented the extreme case for fecal contamination of surface waters because no practices were used to reduce animal impact on the creek. However, animals were located in the landscape to minimize off-site impact by selecting a pasture in the upper portion of the watershed. Animals had been in the grazed watershed since 1 November, one month before water quality sampling began weekly at both springs, both creeks, and below the pond of the grazed watershed. Samples were assayed for total coliform, *E. coli*, and enterococci bacteria. These assays were saturated at microbial numbers of approximately 2500 MPN/100 ml. Rainfall occurred on 24 December (99 mm) and 7 January (46 mm) and raised fecal coliform numbers in surface waters of both watersheds (Fig. 3). By 8 January, the assay for fecal coliforms was saturated at all sites except the spring in the wooded watershed. Total coliform numbers in the creek of the wooded watershed were increased by the rainfall events and remained high, but decreased more rapidly than the creek of the grazed watershed. However, the 95% confidence intervals of the creek in the wooded watershed overlapped the creek and pond overflow of the grazed watershed on the last sample date. The rainfall moved large numbers of bacteria to the pond in the grazed watershed. Total coliform bacteria in the creek and pond remained above the saturation level of

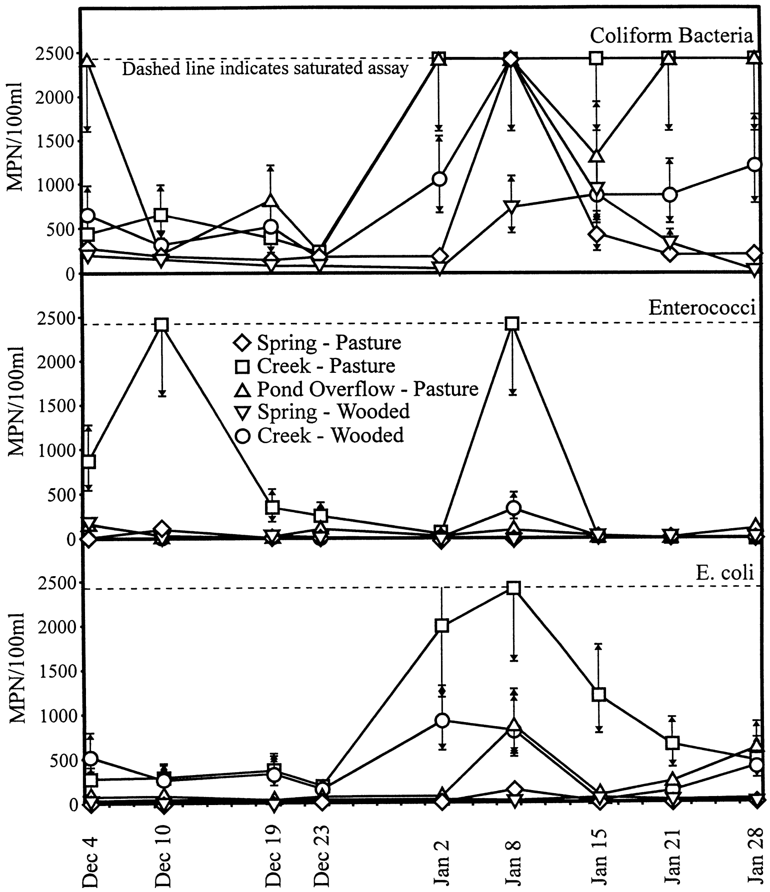

Fig. 3. Most probable numbers (MPN) of total coliforms, *E. coli*, and enterococci bacteria in surface water samples from watersheds with and without domestic livestock. The dashed line indicates the level at which the microbial assay was saturated. Vertical lines indicate the 95% confidence intervals when the interval is greater than the size of the symbol.

the assay for the remainder of the study period. The high levels of coliform bacteria found in the wooded watershed make it difficult to attribute efficacy to management practices designed to reduce off-site fecal contamination by agricultural production systems. High numbers of coliform bacteria from wildlife could account for variation in coliform levels when water quality is otherwise good.

The assay for enterococci bacteria indicated large numbers in the creek of the grazed watershed on two dates (Fig. 3). The first was the result of a relatively small rainfall on 3 December (13 mm) and the second was the result of the previously mentioned events. Rainfall moved the microbes to the sample site from the areas 200–400 m upstream in which cattle had access to the creek. Enterococci in the creek on the wooded watershed were significantly higher on 8 January than in either the grazed watershed's spring or the wooded watershed's spring and were also higher than the pond in the grazed watershed. The creek in the grazed watershed was higher in enterococci bacteria than all other sites on 5 of 9 days. The pond below the grazed watershed was very effective in removing the enterococci bacteria from the creek. The pond was also effective in removing *E. coli* from the grazed watershed (Fig. 3). As expected, numbers of *E. coli* in the pond lagged behind numbers of *E. coli* in the creek of the grazed watershed. The numbers of *E. coli* in both creeks increased as a result of the rainfall event in early January, but the increase in the grazed watershed was of greater magnitude and duration. Numbers of *E. coli* did not respond to the small rainfall events early in the observation period, but did respond to the combined 99 mm and 46 mm rainfall.

Rainfall of 13 mm on 15 January, 13 mm on 19 January, 22 mm on 22 January, and 30 mm on 27 January may have prevented a more rapid decline in the numbers of fecal coliform and *E. coli* bacteria at the sample sites in the grazed watershed. However, these events did not cause increases in enterococci or *E. coli* bacteria. No conservation practices in the grazing system were used to reduce these numbers. Based upon surface hydrology, the cattle in this grazing system were located in the pasture at the top of the watershed and most isolated from the surface water leaving the property. The pond was an effective means of reducing numbers of enterococci and *E. coli* before the water moved off the property. Much of this particular grazing area does not drain to the pond and much larger numbers of fecal bacteria would have been discharged to adjoining property by locating cattle in pastures draining to the creek and bypassing the pond. Both the assay for enterococci and *E. coli* were useful for identifying fecal contamination and provided responses that could be useful in differentiating between areas impacted by grazing lands and areas impacted only by wildlife. Both assays may be valuable in natural resource management and further work on a larger scale is needed to determine if these tests are effective in identifying fecal contamination from land applications of waste.

7. Discussion

The location of 550 poultry operations in the headwaters of the Upper Oconee Watershed and their physical separation from the city of Athens has so far minimized conflicts between agricultural and urban interests. Had the poultry operations been located nearer to the intake for the Athens water supply on the North Oconee River, or closer to the real estate and recreational interests of Lake Oconee, conflicts may have developed. At this point, the watershed is functioning to separate and mitigate conflicting interests. For example, if the concentrations of coliforms observed on the North Oconee River at Maysville were present in the river at the Athens water intake then public pressure may have forced implementation of alternative land uses. Agricultural production along the North Oconee may still come under pressure to reduce perceived or real negative impacts on the quality of the Athens water supply. A new reservoir is planned near Winder that will result in additional pressure on agricultural enterprises nearer the headwaters to reduce impacts on the Middle Oconee and Mulberry Rivers. In contrast, the residents of Lake Oconee have already noted the 30 dairies located near the lake (Oconee Lake Watch, personal communication). Complaints and conflicts have already occurred and volunteer 'Lake Watch' programs are in place. In this case, the location of agricultural production prevents passive mitigation by the watershed and necessitates management practices designed to prevent losses of nutrients and fecal bacteria. For agriculture in the Upper Oconee Watershed, reducing impact in this portion of the watershed must be a top priority. Dairy and beef producers have demonstrated a willingness to implement practices via the Environmental Quality Improvement Program voluntary sign-ups. As the sophistication of the Lake Watch group increases, additional sampling protocols will be incorporated. The planned addition of sampling for phosphorus may increase conflicts with agricultural producers and will probably increase complaints against urban sources, such as Athens (Oconee River) and Greensboro (Richland Creek). A focused effort to reduce agricultural impact on water quality between Athens and Lake Oconee should also be a priority. A proactive stance by agriculture can prevent involvement in a conflict between residents of the lake and the city of Athens.

Implementing improved practices along the North Oconee River can minimize agricultural impacts on the Athens water supply and should be a priority for programs focusing on natural resource protection. Disputes with Athens may be avoided by working with producers closest to the river to adjust animal movements within the constraints of the available property and to implement conservation practices. Eventually the poultry concentration in the headwaters area must be addressed. Imports of feed and concentration of nutrients makes a sustainable solution difficult with the water demand of the growing urban population. Increased urban demand for water from the Middle Oconee may provide an impetus to distribute waste generated by poultry operations over a greater land area and implement practices to limit loss of N, P, and fecal bacteria to surface waters in the northern portions of the watershed. Efforts within the watershed should be focused to develop a planning process in which agricultural and urban interests with responsibility for water quality are shared. Addressing these issues together is essential to avoid short-term counter productive conflicts and to develop a long-term vision for the watershed. ''Each owner's actions are important, not just because they affect that particular piece of land, but also because they affect neighboring land and the health of the larger ecosystems and watersheds in which they occur'' (USDA, 1996).

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